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The experimental and theoretical work performed has related to methods of fabricating superconducting electron device structures on high Tc cuprate superconductors. The Scanning Tunneling Microscope is used for writing, etching, and characterizing mesostructures on crystalline surfaces of Bi2 Sr2 CaCu2O8 (HTS) and related superconductors. Techniques for doping the surface of the HTS, analogous to diffusion doping of Silicon or GaAs surfaces, are of interest, to produce Ohmic contacts, Schottky barriers, and possibly pn junctions. It is expected that all demonstrated processes will be transferable to single crystal HTS films and heterostructures produced by MBE or by Laser Ablation.

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DEPARTMENT OF APPLIED MATHEMATICS AND PHYSICS

Final Technical Report, AFOSR Grant F4960-93-1-0024

Title: " Scanning Tunneling Microscope Methods for Fabrication of Mesoscale Cuprate Superconductor Electron Devices", E. L. Wolf and Yuli M. Ivanchenko, PI's, Department of Physics, Polytechnic University, Six Metrotech Center, Brooklyn, NY 11201

Prepared March 27, 1996 by E. L. Wolf



I. Introduction

The experimental and theoretical work performed has related to methods of fabricating superconducting electron device structures on high T_c cuprate superconductors. The Scanning Tunneling Microscope is used for writing, etching, and characterizing mesostructures on crystalline surfaces of $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ (HTS) and related superconductors. Techniques for doping the surface of the HTS, analogous to diffusion doping of Silicon or GaAs surfaces, are of interest, to produce Ohmic contacts, Schottky barriers, and possibly pn junctions. It is expected that all demonstrated processes will be transferable to single crystal HTS films and heterostructures produced by MBE or by Laser Ablation.

II. Report

Ten papers [P1-P10] have been either published or submitted to refereed publications reporting the supported research. In addition, eleven abstracts [A1-A11] have appeared in the Bulletin of the American Physical Society, including a few poster presentations at Gordon Conferences. These publications, and the three previously submitted Progress Reports quite accurately summarize the results of the supported research.

Thanks to support from this grant, the Ph. D. dissertation of Dr. Frank Lu was completed, and is available via University Microfilms. Dr. Lu has taken a position with Rudolph Research, Inc. A second student, Mr. X. H. Wu is at present writing up his thesis based on work performed under the grant. Mr. Gordon Zhang, whose Ph. D. thesis research was supported in part by this grant has taken a position with a computer firm in Cambridge

MA. Mr. Chao Gao and Mr. Wongyo Kim, formerly a student of Prof. Sarath Meepagala, have also been supported by the grant. Partial support of Research Professor Yuli M. Ivanchenko has been provided also.

PUBLICATIONS

- [P1] Wu, X. H., and Wolf, E. L., "Predicted Carbon-Cluster Field Evaporation from Graphite by Pulsed-Field STM", Surface Science (In Press).
- [P2] Ivanchenko, Yu. M., "Josephson Junction with Magnetically Active Dielectric", Phys. Lett. A180, 154 (1993)
- [P3] Ivanchenko, Yu. M., "Steady-Current Electrodynamics of Layered Superconductors", Phys. Rev. B48 15,966 (1993)
- [P4] Ivanchenko, Yu. M., "Vortex Ring Excitations in Layered Superconductors", Phys. Lett. A183 102, (1993).
- [P5] Tao, H. J., Lu, Farun, Zhang, G, and Wolf, E. L., "Josephson Tunneling in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+x}$ Single Crystal Break Junctions", Physica C224 117 (1994).
- [P6] Wolf, E.L., Chang, A., Rong, Z. Y., Ivanchenko, Yu. M., and Lu, Farun, "Direct STM Mapping of the Superconducting Energy Gap in Single Crystal $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+x}$ ", J. Superconductivity 7 355 (1994).
- [P7] Ivanchenko, Yu. M., "Stabilization of Critical Temperature with Respect to Repulsion in Strong-Coupled Superconductors", Phys. Rev. B50, 6483 (1994).
- [P8] Ivanchenko, Yu. M., "Resistive State in a Long Josephson Junction", Phys. Lett. A 198, 441-446 (1995).
- [P9] Susla, B., Meepagala, S. C., and Wolf, E. L., "Point Contact Studies of High T_c Superconductors", Acta Physica Polonica A 84 315 (1993).
- [P10] Wolf, E. L., "Scanning Tunneling Spectroscopy of the Superlattice Superconductor $\text{Bi}_2\text{Sr}_2\text{Cu}_2\text{O}_8$ ", Superlattices and Microstructures, (In Press).

ABSTRACTS

- [A1] E. L. Wolf and Farun Lu, "Iodine Intercalation of $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$ Studied by X-Ray Photoemission", March 1994 Meeting of the APS, Pittsburgh, PA.
- [A2] Farun Lu and E. L. Wolf, "UHV Scanning Tunneling Microscope Study of Ag

- Adatoms on in-sit-Cleaved $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$ Crystals", March 1994 Meeting of the APS, Pittsburgh, PA.
- [A3] Yu. M. Ivanchenko, "Interaction of Magnetic and Phase Degrees of Freedom in a Josephson Junctions", March 1994 Meeting of the APS, Pittsburgh, PA.
 - [A4] H. J. Tao, Farun Lu, G. Zhang and E. L. Wolf, "Break-Junction (SIS) Josephson Tunneling in Oxygen Annealed $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$ Crystals", March 1994 Meeting of the APS, Pittsburgh, PA.
 - [A5] Zhang, Gordon, and Wolf, E. L., "A Rigid UHV Low Temperature STM Walker", March 1995 Meeting of the APS, San Jose, CA.
 - [A6] Wu., X. H., Wolf, E. L., "Predicted Carbon-Cluster Field Evaporation from Graphite by Pulsed-Field STM", March 1995 Meeting of the APS, San Jose, CA.
 - [A7] Lu, Farun, Wu, X. H., and Wolf, E. L., "Nanoscale Surface Modification of Cleaved $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ Single Crystals With a Scanning Tunneling Microscope", March 1995 Meeting of the APS, San Jose, CA.
 - [A8] Lu, Farun, and Wolf, E. L., "Evidence for Charge Transfer in Iodine Intercalation of the Cuprate Superconductor $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+x}$ ", Abstract of Poster Presentation at 1994 Gordon Research Conference on Superconductivity, Jan. 3-7, 1994, Oxnard CA.
 - [A9] Chang, A., Lu, Farun, Mitra, K., Wu., X. H., and Wolf, E. L., "Scanning Tunneling Microscope Etching and Mesoscale Fabrication on the Cuprate Superconductor $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$ " Abstract of Poster Presentation at 1994 Gordon Research Conference on Microstructure Fabrication, 26 June-July 1, 1994, Brewster Academy, Wolfeboro, NH.
 - [A10] Ivanchenko, Yu. M., "Influence of Repulsion on Critical Temperature in Strong Coupled Superconductors" March 1995 Meeting of the APS, San Jose, CA.
 - [A11] Wolf, E. L., and Ivanchenko, Yu. M., "A System of Josephson Junctions with Nonlocal Interaction", March 1995 Meeting of the APS, San Jose, CA.

PH. D. DISSERTATION COMPLETED

"High Temperature Superconductors Studied by Electron Tunneling and Surface Analysis Techniques", by Farun (Frank) Lu, accepted by Polytechnic University for Ph. D. in Physics, January 1993. (Microfilm or other copies of this dissertation are available from University Microfilms, 300 N. Zeeb Road, Ann Arbor, Michigan 48106).